

Special Issue Honouring Helias A. Udo de Haes: LCA – Past, Present, Future

The Role of SETAC in the Development of LCA

Walter Klöpffer

LCA CONSULT & REVIEW, Am Dachsberg 56E, 60435 Frankfurt am Main, Germany (walter.kloepffer@t-online.de)

DOI: <http://dx.doi.org/10.1065/lca2006.04.019>

Abstract

Background. Life cycle assessments have been performed using different methods before the name was coined since about 1970 in several countries of North America and Europe. It was the merit of SETAC to start a standardization process which culminated in the LCA-guidelines ('A code of practice') in 1993. It is the aim of this paper to trace back this and further LCA-related achievements by SETAC on the basis of documents and personal memories. It may be subjective in the selection and weighting of some events, but objectivity is strived for with regard to the whole and, in my view, singular development.

Results and Discussion. Starting 1990 with two workshops in Smuggler's Notch (Vermont) and Leuven (Belgium), SETAC and SETAC Europe organized several workshops during which important topics (framework, impact assessment, data quality, etc.) were treated and published in the form of reports which are still available. The main contribution by CML and its head, Helias Udo de Haes, was a practical method of impact assessment, transforming the formerly more "technocratic" LCA (energy, resources, waste) into an instrument of environmental assessment of product systems. In addition, important contributions to the allocation problem were made. Starting in 1993, ISO took over the leadership in standardization and SETAC started the famous working groups in North America and Europe, often dealing with the same topics in parallel. Due to the different cultures, the results were frequently complimentary rather than harmonic. The CML-method of LCIA, widely accepted in Europe, had to wait for about 10 years to be accepted at the other side of the Atlantic. It was helpful that SETAC – meanwhile a global organization – looked for a partner in order to implement LCA all over the world. This partner was found in the 'United Nations Environmental Programme' (UNEP) and the UNEP/SETAC Life Cycle Initiative was officially launched by Klaus Töpfer in Prague in April 2002.

SETAC also assumed an important role in communicating LCA via publications: workshop and conference reports, the 'code of practice', working group results and LCA News Letters. The annual meetings offered forums for LCA scientists, practitioners and users, well prepared by the LCA Steering Committee (SETAC Europe) and the LCA Advisory Group (SETAC North America).

Recommendations. The main recommendation to SETAC is to adhere to LCA as the main environmental assessment tool for products and to expand it to a true sustainability assessment tool by adding Life Cycle Costing (LCC) and a still to be invented 'Social Life Cycle Assessment'. SETAC is to remain the scientific arm within the UNEP/SETAC LC Initiative, without losing its identity. Working groups should be global rather than regional in the future, as suggested by the SETAC Europe LCA Steering Committee at the 2004 World Congress in Portland, Oregon.

Keywords: LCA; LCC; SETAC; sustainability assessment; UNEP/SETAC LC Initiative

1 The Early Development of LCA

To a certain degree, Life Cycle Assessment, as we know it today, was created by SETAC. The report on the Smugglers Notch (Vermont) workshop, August 1990 [1], is the first document in which the name of the method and a general structure, still valid today, was presented. Only one month after this workshop, a European workshop took place in Leuven [2], in which a similar aim was followed: to bring together the groups working on life-cycle based assessment methods. This was necessary on both sides of the Atlantic Ocean, since the methods were not really new but uncoordinated and far away from a harmonization, not to speak from standardization.

The first 'proto-LCAs', as we may call the early ecobalances in retrospect, were conducted at the Midwest Research Institute (MRI) and named 'Resource and Environmental Profile Analysis (REPA)' [3]. The idea of the method has been attributed to Harry Teasley, then at Coca-Cola company, the first sponsor of a REPA study in 1969 [4]. Franklin Associates, the company which emerged from the REPA working group at MRI, continued to use the name chosen for the method and has been performing many studies of this type, perhaps more than any other group in the field.

In the years following the introduction of the method, similar 'cradle-to-grave', product related environmental assessments were developed in Europe, mainly in Great Britain [5], Germany [6], Switzerland [7], Sweden [8] and France [9]. Due to the increasing problems of waste disposal, packaging was the main topic of the proto-LCAs and still is important today. Energy, and especially the fossil fuels, also gained importance in the 1970's. When the (two) oil-crises of this decade were overcome, the interest in LCA-type studies declined, but not for long. At the end of the 1980's, an unprecedented and still not fully understood¹ steep increase of the demand for ecobalance studies occurred. This finally led to the development mentioned in the first paragraph. Industrial companies (e.g. Procter and Gamble (P&G), Tetra Pak) joined contract research companies (e.g. Battelle, Fraunhofer), public research institutes (e.g. EMPA, CML) and genuine LCA groups (e.g. Franklin, Écobilan) under the

¹ One of the referees commented on this point saying, "I understand this as a consequence of broadly developing policy, with conflicting demands in the chain, and leaving the domain of end-of-pipe technologies in policy. Problem shifting came up as a genuine problem (only partly solved by LCA.)". This is a good comment, I think. The second half of the 1980's was a successful time for environmental efforts anyway (Brundtland report, Vienna convention and Montreal protocol on freons and the ozone layer, acid rain activities, etc.), paving the way for great UNEP world conference in Rio de Janeiro 1992.

leadership of SETAC. The result was Life Cycle Assessment (previously, Life Cycle Analysis was used alternatively, a term which is obsolete today for designating the method; it is still used as a synonym for 'Life cycle thinking' or other forms not strictly corresponding to the 'SETAC/ISO' LCA).

2 The 'Heroic Time' of SETAC (1990–1993)

The development of LCA following the impressive start was led by SETAC (North America) and SETAC-Europe and coordinated by LCA advisory groups at both sides of the Atlantic. The European group proudly called itself LCA steering committee, and still does. Nick de Oude (Procter & Gamble), a founding member and executive director of SETAC-Europe, should be remembered as the 'spiritus rector' of these activities in Europe and as the founder of the 'Society for the Promotion of Lifecycle Development (SPOLD)', best known for the development of a common LCI data transfer format [10]. LCA News Letters were published by SETAC and SETAC-Europe in the 1990's, a highly appreciated SETAC activity which was not restricted to members. It survives in restricted scope in the LCA section of the SETAC GLOBE, edited by Bruce Vigon.

SETAC's main contribution to the development of LCA in the period 1990–93 consisted in organizing and publishing a series of workshops about different aspects of LCA [11]:

- A Technical Framework for Life-Cycle Assessment, Smugglers Notch (1990) [1]
- Life-Cycle Assessment, Leiden (1991) [12]
- Conceptual Framework for Life-Cycle Impact Analysis, San Destin (1992) [13]
- Conceptual Framework for Life-Cycle Data Quality, Wintergreen (1993) [14]
- Guidelines for Life-Cycle Assessment: A 'Code of Practice', Sesimbra (1993) [15]

Whereas the inventory phase (LCI) was already well developed in the proto-LCAs like REPA, most of which would be called LCIs today, the impact assessment component (LCIA) requested by SETAC [1,12,13,15] was new. It brought the environmental sciences into the formerly more engineering dominated method and Helias Udo de Haes and his coworkers and colleagues at CML, Leiden, presented a method of LCIA that essentially has dominated the discourse as well as the actual application. Gabathuler [16] described in detail, how this development took place, using the methods of science sociology. The CML method of 'environmental themes' or impact categories was first presented internationally by Udo de Haes in Leiden 1991 [17] and soon after was followed by the publication of the first 'Dutch Guide' in 1992 [18]. This approach is actually a consequent extension of the easy-to-use aggregation methods (for energy, solid waste, and toxic emissions to air and water) developed in Switzerland by researchers at EMPA and ETH [19,20]. The CML method is much more detailed and scientific, however, and contains characterization factors for about 10 impact categories. The method was immediately accepted in Europe, e.g. in Germany and Sweden [21,22].

In North America, SETAC took another, perhaps complementary way. The Impact assessment workshop in Sandestin 1992 [13] discussed a broad range of possible approaches, based on a stressor concept, and considered different levels of sophistication. No recommendation for a specific method was given, however. As a result of these different opinions about LCIA, which may be routed in a deeper discrepancy about environmental assessment² in general, a kind of schism between the LCIA philosophies at both sides of the Atlantic developed, which has been ended not before the advent of the new century.

The workshop series of this period culminated in the Sesimbra workshop, which took place after the first SETAC World Congress in Lisbon, March 1993 in a (former) fishing village. It was organized jointly by SETAC (North America) and SETAC-Europe and assembled ca. 50 LCA-experts. The result was a 69-page LCA Guideline 'A Code of Practice'³ [15]. The guideline reaffirmed essential points from earlier workshop reports, especially the general structure with a slightly differing wording and a clear statement about the importance of the first component 'Goal definition and scoping'. A component 'Valuation', proposed in Leiden [12], was accepted as a 3rd step of Impact Assessment after 'Classification' and 'Characterization', but not as a component of its own. It should be noted that a list of 10 impact categories and three 'General Areas for Protection' were given. As can be seen from this short description, the ideas put forward by Helias Udo de Haes and his CML team were incorporated in this important guide, although specific classification factors – badly needed by the practitioners – were not recommended. This did not change later during the standardization by ISO (14042) [28]. It should be stressed that the work by SETAC, summarized and codified in [15], was the basis of the standardization work which started soon after the publication of the 'Code of Practice'.

One reason for the establishment of the guidelines [15] and later of the ISO standards 14040-43 was the considerable misuse of the 'proto-LCAs' in comparative product assessments for marketing purposes. SETAC's membership and management are composed equally by researchers from academia, industry (including consultancy), and governmental organizations. This gives SETAC the necessary authority and credibility to prescribe firmly a fair and honest behavior for LCA commissioners as well as practitioners. Furthermore, it was recommended that an 'interactive peer review process' should be performed in order to increase the quality and the credibility of LCAs (Chapter 7 in [15]). ISO, later, even strengthened this aspect and made the 'critical review' according to the panel method obligatory for LCAs containing comparative assertions, but did not prescribe the interactive variant of reviewing [23,24].

² In Europe, the precautionary principle is widely accepted in environmental assessment; for LCIA this means that 'potential impacts' (hazards) are accepted for assessments as opposed to real impacts (risks) which are difficult, if not impossible, to quantify in the framework of LCA/LCIA

³ The title originally planned of 'Code of Conduct' was changed, since the word "code" has a strong juridical meaning, especially in the US

At the end of the period, LCA was an established method with a clear structure and rules how it should be performed; this is much more than most environmental assessment methods can claim. The publication of LCAs and methodological articles was still a weak point. The SETAC-Europe LCA Steering Committee therefore adopted a proposition made by Allan Astrup Jensen and suggested that SETAC should publish a LCA journal of its own. At least one publishing house in the US showed a concrete interest, but it was finally decided by SETAC that the official journal edited by the society 'Environmental Toxicology and Chemistry' will accept papers related to LCA [25]. This decision paved the way for a private initiative by ecomed publishers and the author of this article to create the journal you have in your hands (or PC) [26]. SETAC's second journal 'Integrated Environmental Assessment and Management (IEAM)', presented at the 4th SETAC World Congress in Portland, Oregon, November 2004, publishes LCA-related articles.

3 The Troublesome Way Towards an Unified Methodology for LCA (1994–2001)

The general structure of LCA established by SETAC, the way to international standardization was free. In the period presented in this section, leadership in this task was assumed by ISO. Four standards (ISO 14040–43) have been prepared by delegates from 24 countries, 16 further countries sent observers [23,27–29]. This great success poses the question why LCA has been the one and only environmental assessment method judged worthy to be standardized by ISO? Of course, we are sure that the basic idea of LCA is correct and immediately convincing. Furthermore, the method proved to be feasible in praxis. But there are at least two other factors which contributed to success:

- LCA came timely in a period when the products were recognized as the main outputs ('emissions') of industry causing environmental concern, and
- LCA found in SETAC a trustworthy, international scientific organization that promoted the method with great enthusiasm and skill.

Within a few years, LCA development had shifted from consultancy and industry towards academia. The simple models and numerous assumptions inherent in the 'home-made' proto-LCAs were scrutinized by professors and PhD-students, and many experienced LCA practitioners (I do not exclude myself) were often not amused by this call for scientific rigorosity, which frequently cannot be substantiated in praxis. First of all, the belief in the objectivity of LCI was shattered by the finding that allocation cannot be done in a scientifically unambiguous way [30], a problem known in the economic sciences since 1848 [31,32]. A workshop on the topic of allocation in LCA was organized 'under the auspices of SETAC-Europe' in Leiden, in February 1994 [33] that brought deep insights into the nature of the problem. SETAC-Europe was officially represented with a talk by Dennis Postlethwaite, the chairman of the LCA Steering Committee. Gjalte Huppes presented 'A general method for allocation in LCA' [69]. This presentation was based on a chapter dealing with LCA in a book published by Huppes in

1993 [70] and stressed the advantage of allocation according to the economic values, e.g. of co-products. Simple rules for allocation in open-loop recycling were reviewed and analyzed by the author [34] and by Ekvall & Tillman [35].

The next problem concerned LCIA; addressed in several SETAC workshops [1,11–13,15,17], the methodology had to be discussed in a broader context and with a larger public. The occasion was the fourth SETAC-Europe Annual Meeting in Brussels, April 1994, during which a special symposium on LCIA was organized and published as a SETAC-Europe Report [36]. From this symposium, I vividly remember a paper presented by José Potting [37] in which she advocated the inclusion of spatial effects into LCIA. Actually this, as well as time was neglected in most early LCAs and still is.

Many methodological problems were now treated – for years and in great detail – in SETAC working groups. In this connection, it should be mentioned that the role of the steering/advisory LCA committees cannot be overestimated⁴. The working groups are installed and supervised by these committees which also prepare the regular LCA sessions at the annual SETAC and SETAC-Europe meetings, decide about publications, etc.

In a first wave, the following working groups delivered reports published before the year 2000:

- Towards a Methodology for Life Cycle Impact Assessment. SETAC-Europe (1996) [38]
- Simplifying LCA: Just a Cut? SETAC-Europe (1997) [39]
- Life-Cycle Impact Assessment: The State-of-the-Art. SETAC (NA) (1997,1998) [40]
- Streamlined Life-Cycle Assessment SETAC (NA) (1999) [41]

As can be seen, the two main topics, Impact Assessment (LCIA) and streamlined/simplified LCA were treated and published separately in Europe and in North America. In the following, the focus will be on LCIA, since in this field there are the main difficulties, also with regard to the international standardization which run in parallel and expected the scientific input. What should they have standardized, if there is no common practice? The solution was Solomonic: ISO 14042 [28] took over the 'European'⁵, i.e. CML structure of the component, but refrained from any concrete recommendations about particular impact categories, indicator models or classification factors.

The two LCIA reports [38,40] prepared on both sides of the Atlantic are complimentary. Whereas the 'European' report [38] tried to give advice (as comprehensive and concrete as possible at that time), the 'American' report [40] deals with the general problems and is sceptical about suggesting spe-

⁴ One referee encouraged me to put more emphasis on that point: "The author should expand on the role of the advisory and steering groups within SETAC. They were the driving force within SETAC to allow SETAC's role to be realized." I agree.

⁵ There is no real European LCIA methodology – although 'CML' is widely accepted –, due to the controversy endpoint vs. midpoint modelling, ISO 14042 giving no preference to one or the other approach. CML is better suited for midpoint modelling

cific impact categories. It is more rooted on the 'Sandestin Report' [13], whereas the European report [38] is based on the results of the Leiden Workshop [12].

It soon turned out that even (or in particular) the European effort towards a unified LCIA methodology was not yet sufficient to get accepted by the whole LCA community. Sessions on LCIA were organized at the annual meetings following the Brussels (4th) annual meeting in 1994. During the Bordeaux (8th) annual meeting in 1998, a second wave of working groups was started with a planned duration of three years. The LCIA topic was followed up in a large group headed by Helias Udo de Haes. Subgroups had to be formed to handle the broad topic and the number of participants. Within one year, the framework paper was published in *The International Journal of Life Cycle Assessment* [42,43] and ready to be discussed during the SETAC-Europe 1999 annual meeting in Leipzig. A discussion with SETAC members from North America took place publicly, e.g. [44,45] and not in separate working groups. At the end of the working phase, during the drafting of the chapters of the book to be published, suddenly some confusion emerged about the 'Areas of Protection' or 'Safeguard Subjects' and the correct system boundaries between technosphere ('economy') and environment. This intense and in parts funny discussion was initiated by David Pennington and conducted entirely by email at the turn of the century (December 2000 to March 2001). It became known as the 'areas of protection debate' and was recorded for the internet-based 'Global LCA Village' [46]. The manuscripts of the 8 chapters were finally ready for review in the end of 2001 and published by SETAC Press 2002 in the award-winning book 'Life-Cycle Impact Assessment: Striving Towards Best Practice' [47].

In the period reviewed in this section, another workshop took place and was published by SETAC:

Public Policy Applications of Life-Cycle Assessment. Proceedings from the Workshop on Application of Life-Cycle Assessment for Public Policy. SETAC (NA) 1994 [48].

Within the second wave of SETAC-Europe working groups, several other reports were produced and finally published:

- Code of Life Cycle Inventory Practice [49]
- Life cycle management (LCM) [50]
- The working environment in LCA [51]
- Scenarios in Life-Cycle Assessment [52]
- Life-Cycle Assessment in Building and Construction [53]

These interesting developments cannot be discussed here in detail. They show both a deepening (improvement of method) and a broadening of LCA (application in industry and management).

4 The UNEP/SETAC Life Cycle Initiative (2002–2005)

The cooperation between the United Nations Environmental Programme (UNEP) and SETAC was officially started by Klaus Töpfer (Executive director of UNEP), on April 28 2002, in Prague [54]. This launch had been preceded by several years of preparations, both scientific/technical and organizational ones. One prerequisite for this cooperation

was the transformation of SETAC into a truly global organization in the late 1990's. Only in that way could SETAC become an adequate partner of UNEP. Another reason has been UNEP's need for implementing sustainable development, proclaimed as the most important goal of humankind in the 21st Century in Rio de Janeiro 1992 [55] and confirmed in Johannesburg in 2002 [56]. Sustainability is not easy to measure, but if there is a solution, it will be based on methods derived from life cycle thinking [57], with LCA as the core element. Thus, a co-operation between SETAC and UNEP's Production and Consumption Branch (Paris), was a logical and promising one from the beginning.

The key people from SETAC's side in the negotiations were Jim Fava [58], Helias Udo de Haes and Olivier Jolliet [59]. Jim Fava is now vice-chair and SETAC representative of the UNEP/SETAC International Life Cycle Panel (ILCP), Helias Udo de Haes is the technical director. In this position, he is responsible for the following three programs and reports directly to the ILCP [60].

- LCIA, program manager: Olivier Jolliet (Switzerland)
- LCI, program manager: Greg Norris (USA), and
- LCM, program manager: Konrad Saur (Germany)

The work within the three programs is done by three to four task forces per program [62], e.g. in LCIA there are four task forces on

- LCIA information system
- Natural resources and land use
- Toxicity impacts
- Transboundary impacts

In LCI, the following task forces are active:

- LCI database registry
- LCI database characteristics and quality
- LCI methodological consistency
- LCI databases and capacity building

Three task forces have been set up in Life Cycle Management (LCM):

- LCM handbook
- Life cycle based product development
- Communication on life cycle information.

More recently, the implementation of the methods at a global level has gained momentum, since a purely scientific development does not necessarily improve the presently (despite many encouraging activities) very low level of sustainability in the industrialized as well as in the developing world.

5 The Future of LCA in SETAC

The future, of course, cannot be known. But it is possible to analyze the present state and to draw conclusions for the near future and to identify fields of activities in which SETAC can continue its proud and successful practice in life-cycle based methods. This cannot be done without a look at the recent activities in the UNEP/SETAC Life Cycle Initiative.

Within the few years of its existence, this initiative has developed an astonishing activity, not only within the three programs, but also in organizing and co-organizing workshops, symposia and conferences; publications in different

media (e.g. a co-operation with Int J LCA which has become the associated journal of the initiative January 2003 [61]), including a very informative and well-structured web site [62]. This success, which is also a great achievement by SETAC (as one of the parents of this bright child), on the other hand, is considered as a problem by some SETAC members working in the LCA field. The reason is, of course, the lack of direct influence on the activities of this offspring which also lives with the other parent, so to speak⁶. Several fields traditionally dealt with by SETAC and SETAC-Europe are now being developed further within the initiative (LCI, LCIA, LCM).

SETAC is the scientific arm of the initiative and therefore the main responsibility for the scientific part is with SETAC or its members working within the programs and task forces. The continuity should be guaranteed by the LCA leaders within ILCP. The question remains, what can and should SETAC do on its own? There are some important activities by the LCA advisory groups which have to be continued:

- organizing the LCA sessions at the annual meetings in Europe and North America and at the world conferences
- continue the annual case studies symposia in a form to be discussed in the LCA steering committee after 2005
- follow up activities like the LCA students program, etc.

As important as these and other activities are, they alone cannot assure SETAC's leadership in life-cycle based assessment methods, a leadership which has been attributed to SETAC since 1990. The situation is similar as 10 years ago, when ISO took over the leadership in standardizing LCA. SETAC reacted by going into the depth in developing further the method (section 3). This is in principal the direction we should go again. It makes no sense to double activities which are well done within the initiative (section 4), albeit with the main aim of a global implementation (UNEP's part). It is now time to mention two current working groups which may be especially promising for further 'cutting edge' activities:

- Life Cycle Costing (chair: David Hunkeler, co-chairs: Gerald Rebitzer, Kerstin Lichtenwort); for an introduction to LCC, see [63]
- Input-Output and Hybrid Life Cycle Assessment (chair: Sangwon Suh), organized together with ISIE⁷ [64]

The first working group, which is nearer to my recent field of interest and to which I belong, aims at developing a guide for LCC compatible with LCA. The important point is to find equal and consistent system boundaries for both methods [57]. A manuscript for the working group report (to be submitted for review to SETAC Press) is expected for the end of 2005. Why is LCC so important for product assessment? The reason is that sustainability is the ultimate goal of product development, not (only) compatibility with the environment [55,56,65,71]. Ecological, economic and social aspects have to be brought together and assessed in or-

der to get the full picture. This is well known and often called the 'triple bottom line' in LCM. The methods which are used, however, still remind one of the proto-LCAs discussed in section 1. It is therefore a major goal to develop a consistent sustainability assessment method based on LCA (standardized), LCC (standardization in development) and Social LCA (still in infancy [57,71]).

Another important item in LCA – and still a deficiency – is the inability of LCIA to incorporate non-chemical impacts to ecosystems, e.g. the invasive species and certain biotechnologically modified organisms [66,67]. What kind of indicators could we think of and develop to be consistent with LCIA. Or, alternatively, how can a tool be developed, which is compatible with LCA as LCC will be in the near future? Needless to say that such questions are not restricted to Europe and North America; the long-time isolated ecosystems of Australia and New Zealand are especially vulnerable.

Sustainable Consumption turned out to be a field of considerable interest, since consumers decide which products are purchased and used and which not [72]. This field has not yet been sufficiently discussed in SETAC's LCA community, although LCA has been proposed as the main assessment tool at the World Summit on Sustainable Development 2002 in Johannesburg [56]. This has been criticized by Hertwich [73] with the argument that LCA is not suitable for studying consumption patterns. This may be true, but there remains a strong connection to the comparative assessment of single products and groups of products (actually this is the strength of LCA) and thus to product labeling. Interestingly, ISO 14025 (Typ III labelling) is now being enacted as an international standard which is closely related to the ISO 14040ff family [74]. Actually, LCA is the basis of ISO 14025, together with a set of rules how the LCA results should be used in preparing the Environmental Product Declarations according to the new standard. It is not yet clear what this means for the further development of LCA methodology, including the critical review procedure.

It is recommended that the SETAC working groups, enacted and surveyed by the LCA advisory/steering committees, should continue to play a major role in the development of life-cycle based assessment and management methods. Only in that way, the best use can be made of the knowledge owned by our members dedicated to LCA and related fields. The new working groups should be conceived as global groups from the beginning. This is made possible by the new communication tools. The SETAC Europe LCC group mentioned above already has a global membership, although experts from Europe dominate.

This last section, of course, is a rather personal view about possible future developments of LCA and related assessment methods. It should induce a broad discussion in the LCA community and actions by the LCA advisory/steering groups and the councils of SETAC at all geographical units. In this regard, it is a good sign that, at the level of SETAC World, a new advisory group on sustainability was formed, chaired by Norbert Scholz and Steve Klaine [68]. As a starting point, a round table debate on this subject has been organized during the SETAC North America (26th) Annual Meeting in Baltimore, November 2005 [75].

⁶ The secretariat of the UNEP/SETAC LCI initiative is accommodated in UNEP's Paris office

⁷ International Society of Industrial Ecology (president: John Ehrenfeld); this society acted as co-organizer of the SETAC-Europe LCA Case study symposia in Barcelona (2002), Lausanne (2003) and Bologna (2005). ISIE is linked with the Journal of Industrial Ecology, published by MIT Press; editor-in-chief: Reid Lifset.

References

- [1] Fava JA, Denison R, Jones B, Curran MA, Vigon B, Selke S, Barnum J (eds) (1991): SETAC Workshop Report: A Technical Framework for Life-Cycle Assessment. August 18–23, 1990, Smugglers Notch, Vermont. SETAC, Washington, DC
- [2] Life Cycle Analysis for Packaging Environmental Assessment. Proceedings of the Specialised Workshop, Leuven, Belgium - September 24/25 (1990)
- [3] Hunt R, Franklin WE (1996): LCA – How it Came About. Personal Reflections on the Origin and the Development of LCA in the USA. *Int J LCA* 1 (1) 4–7
- [4] Hunt RG, Sellers JD, Franklin W (1992): Resource and Environmental Profile Analysis: A Life Cycle Environmental Assessment for Products and Procedures. *Environ Impact Assess Rev* 12, 245–269
- [5] Boustead I (1996): LCA – How it Came About. The Beginning in UK. *Int J LCA* 1 (3) 147–150
- [6] Oberbacher B, Nikodem H, Klöpffer W (1996): LCA – How it Came About. An Early Systems Analysis of Packaging for Liquids Which Would be Called an LCA Today. *Int J LCA* 1 (2) 62–65
- [7] Fink P (1997): LCA – How it Came About. The Roots of LCA in Switzerland: Continuous Learning by Doing. *Int J LCA* 2 (3) 131–134
- [8a] Lundholm MP, Sundström G (1985): Ressourcen und Umweltbeeinflussung. Tetrabrik Aseptic Kartonpackungen sowie Pfandflaschen und Einwegflaschen aus Glas. Malmö
- [8b] Baumann H, Tillman A-M (2004): Section 2.1 in: The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application. ISBN 91-44-02364-2. Studentlitteratur, Lund, pp 44–51
- [9] Blouet A; Rivoire E (1995): L'Écobilan. Les produits et leurs impacts sur l'environnement. ISBN 2-10-002126-5. Dunod, Paris
- [10] Singhofen A, Hemming CR, Weidema BP, Grisel L, Bretz R, Smet B de t, Russel D (1996): Life Cycle Inventory Data. Development of a Common Format. *Int J LCA* 1 (3) 171–178
- [11] SETAC (ed) (2003): LIFE-CYCLE ASSESSMENT and SETAC: 1991–1999. CD-ROM, ISBN 1-880611-74-0, Pensacola (Florida)
- [12] SETAC-Europe (ed) (1992): Life-Cycle Assessment. Workshop Report 2–3 December 1991, Leiden (The Netherlands)
- [13] Fava J, Consoli FJ, Denison R, Dickson K, Mohin T, Vigon B (eds) (1993): A Conceptual Framework for Life-Cycle Impact Assessment. Workshop Report. SETAC and SETAC Foundation for Environ. Education. Sandestin, Florida, February 1–7, 1992, published by SETAC
- [14] Fava J, Jensen AA, Lindfors L-G, Pomper S, De Smet B, Warren J, Vigon B (eds) (1994): Life-Cycle Assessment Data Quality: A Conceptual Framework. Workshop Report. SETAC and SETAC Foundation for Environ. Education. Wintergreen, Virginia, October 1992. Published by SETAC
- [15] Society of Environmental Toxicology and Chemistry (SETAC) (1993): Guidelines for Life-Cycle Assessment: A 'Code of Practice'. Based on a Workshop at Sesimbra, Portugal, March 31–April 3 1993, Brussels and Pensacola, Florida (USA)
- [16] Gabathuler H (1998): The CML Story. How Environmental Sciences Entered the Debate on LCA. *Int J LCA* 2 (3) 187–194
- [17] Udo de Haes HA (1992): General Framework for Environmental Life-Cycle Assessment of Products. In: SETAC-Europe (Ed.) (1992): Life-Cycle Assessment. Workshop Report 2–3 December 1991, Leiden (The Netherlands), pp 21–28
- [18] Heijungs R, Guinée JB, Huppes G, Lankreijer RM, Udo de Haes HA, Wegener-Sleeswijk A, Ansems AMM, Eggels PG, van Duin R, de Goede HP (1992): Environmental Life Cycle Assessment of Products. Guide (Part 1) and Backgrounds (Part 2), prepared by CML, TNO and B&G. (in Dutch) Leiden. English Version 1993
- [19] Bundesamt für Umweltschutz (BUS), Bern (ed) (1984): Oekobilanzen von Packstoffen. Schriftenreihe Umweltschutz, Nr. 24, Bern
- [20] Habersatter K, Widmer F: Oekobilanzen von Packstoffen. Stand 1990. In: Bundesamt für Umwelt, Wald und Landschaft – BUWAL (ed) (1991): Schriftenreihe Umwelt Nr. 132, Bern
- [21a] Klöpffer W, Renner I (1993): Methodik der Wirkungsbilanz im Rahmen von Produkt-Ökobilanzen unter Berücksichtigung nicht oder nur schwer quantifizierbarer Umwelt-Kategorien. Report by C.A.U. GmbH, Dreieich, prepared for Umweltbundesamt (UBA), Berlin. ISSN 0722-186X. Published in: UBA-Texte 23/95, Berlin, 1995
- [21b] Klöpffer W (1995): Exposure and Hazard Assessment Within the Life Cycle Impact Assessment. *ESPR – Environ Sci & Pollut Res* 2 (1) 38–40
- [22] Lindfors L-G, Christiansen K, Hoffmann L, Virtanen Y, Juntilla V, Hanssen O-J, Rønning A, Ekvall T, Finnveden G (1995): Nordic Guidelines on Life-Cycle Assessment. Nordic Council of Ministers. Nord 1995:20, Copenhagen
- [23] International Standard Organization – ISO (1997): Environmental management – Life cycle assessment – Principles and framework. ISO 14040
- [24] Klöpffer W (2005): The Critical Review Process According to ISO 14040-43: An Analysis of the Standards and Experiences Gained in their Application. *Int J LCA* 10 (2) 98–102
- [25] Fava JA (1994): Life-Cycle Assessment: A New Way of Thinking (Editorial). *Environ Toxicol Chem* 13, 853–854
- [26] Klöpffer W (1996): Editorial in the first issue of 'The International Journal of Life Cycle Assessment', *Int J LCA* 1 (1) 3
- [27] International Standard Organization – ISO (1998): Environmental management – Life cycle assessment: Goal and scope definition and inventory analysis. ISO 14041
- [28] International Standard Organization – ISO (2000): Environmental management – Life cycle assessment: Life cycle impact assessment. ISO 14042
- [29] International Standard Organization – ISO (2000): Environmental management – Life cycle assessment: Interpretation. ISO 14043
- [30] Heintz B, Baisnée P-F (1992): System Boundaries. In: SETAC-Europe (ed) (1992): Life-Cycle Assessment. Workshop Report 2–3 December 1991, Leiden, pp 35–52
- [31] John Stuart Mill (1848): Principles of Political Economy, Book III, Chapter XVI §1, 1st edition, London (facsimile: Verlag Wirtschaft u. Finanzen, Düsseldorf 1988)
- [32] Riebel P (1955): Die Kuppelproduktion. Betriebs- und Marktprobleme. Westdeutscher Verlag, Köln
- [33] Huppes G, Schneider F (eds) (1994): Proceedings of the European Workshop on Allocation in LCA at the Centre of Environmental Science (CML) of Leiden University, Leiden 24th and 25th of February 1994. Under the Auspices of SETAC-Europe, Brussels
- [34] Klöpffer W (1996): Allocation Rules for Open-Loop Recycling in Life Cycle Assessment – A Review. *Int J LCA* 1 (1) 27–31
- [35] Ekvall T, Tillman A-M (1997): Open-Loop Recycling: Criteria for Allocation Procedures. *Int. J LCA* 2 (3) 155–162
- [36] Udo de Haes HA, Jensen AA, Klöpffer W, Lindfors L-G (eds) (1994): Integrating Impact Assessment into LCA • Proceeding of the LCA symposium held at the Fourth SETAC-Europe Congress, 11–14 April 1994, Brussels. Published by Society of Environmental Toxicology and Chemistry – Europe, Brussels
- [37] Potting J, Blok K (1994): Spatial aspects of Life-Cycle Impact Assessment. In: Udo de Haes HA, Jensen AA, Klöpffer W,

- Lindfors, L-G (eds) (1994), Integrating Impact Assessment into LCA. Proceeding of the LCA symposium held at the Fourth SETAC-Europe Congress, 11–14 April 1994, Brussels, pp 91–98
- [38] Udo de Haes HA (1996): Towards a Methodology for Life Cycle Impact Assessment. ISBN 90-5607-005-3. Published by SETAC-Europe, Brussels
- [39] Christiansen K (ed) (1997): Simplifying LCA: Just a Cut? Final Report of the SETAC-Europe LCA Screening and Streamlining Working Group. ISBN 90-5607-006-1. Published by SETAC-Europe, Brussels
- [40] Barnthouse L, Fava JA, Humphreys K, Hunt R, Laibson L, Noesen S, Norris G, Owens J, Todd J, Vigon B, Weitz K, Young J (eds.) (1998): Life-Cycle Impact Assessment: The State-of-the-Art. Report of the SETAC Life-Cycle Assessment (LCA) Impact Assessment Workgroup. 2nd edition. Society of Environmental Toxicology and Chemistry. Pensacola, Florida, USA
- [41] Todd JA, Curran MA (eds) (1999): Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup. Published by SETAC and SETAC Foundation for Environmental Education, Pensacola, Florida, USA
- [42] Udo de Haes HA, Jolliet O, Finnveden G, Hauschild M, Krewitt W, Müller-Wenk R (1999): Best Available Practice Regarding Impact Categories and Category Indicators in Life Cycle Impact Assessment. Part 1. Int J LCA 4 (2) 66–74
- [43] Udo de Haes HA, Jolliet O, Finnveden G, Hauschild M, Krewitt W, Müller-Wenk R (1999): Best Available Practice Regarding Impact Categories and Category Indicators in Life Cycle Impact Assessment. Part 2. Int J LCA 4 (3) 167–174
- [44] Owens JW (1998): Life Cycle Impact Assessment: The Use of Subjective Judgments in Classification and Characterization. Int J LCA 3 (1) 43–46
- [45] Owens JW (1999): Owens, Why Life Cycle Impact Assessment is Now Described as an Indicator System. Int J LCA 4 (2) 81–86
- [46] Klöpffer W (2002): The Areas of Protection Debate (Preface). Int J LCA 7, 94; Int J LCA 7, 10A; Electronic version In: Gate to EHS: Global LCA Village <DOI: <http://dx.doi.org/10.1065/ehs2002.03.014>>
- [47] Udo de Haes HA, Finnveden G, Goedkoop M, Hauschild M, Hertwich EG, Hofstetter P, Jolliet O, Klöpffer W, Krewitt W, Lindeijer E, Müller-Wenk R, Olsen SI, Pennington DW, Potting J, Steen B (eds) (2002): Life-Cycle Impact Assessment: Striving Towards Best Practice. ISBN 1-880611-54-6. SETAC Press, Pensacola, Florida, USA
- [48] Allen DT, Consoli FJ, Davis GA, Fava JA, Warren JL (eds) (1997): Public Policy Applications of Life-Cycle Assessment. Proceedings from the Workshop on Application of Life-Cycle Assessment for Public Policy. 14–18 August 1995, Wintergreen, Virginia, USA. ISBN 1-880611-18-x, published by SETAC
- [49] Beaufort-Langeveld ASH de, Bretz R, van Hoof G, Hischier M, Jean P, Tanner T, Huijbregts M (eds) (2003): Code of Life-Cycle Inventory Practice. (book + CD) ISBN 1-880611-58-9. SETAC Press, Pensacola, Florida, USA
- [50] Hunkeler D, Saur K, Rebitzer G, Finkbeiner M, Schmidt W-P, Jensen AA, Stranddorf H, Christiansen K (2004): Life-Cycle Management. ISBN 1-880611-77-5. SETAC Press, Pensacola, Florida, USA
- [51] Poulsen PB, Jensen AA, Antonsson A-B, Bengtsson G, Karling M, Schmidt A, Brekke O, Becker J, Verschoor AH (eds) (2004): The Working Environment in LCA. ISBN 1-880611-68-6 SETAC Press, Pensacola, Florida, USA
- [52] Rebitzer G, Ekvall T (eds) (2004): Scenarios in Life-Cycle Assessment. ISBN 1-880611-57-0. SETAC Press, Pensacola, Florida, USA
- [53] Kotaji S, Schuurmans A, Edwards S (eds) (2003): Life-Cycle Assessment in Building and Construction: A State-of-the-Art Report, 2003. ISBN 1-880611-59-7. SETAC Press, Pensacola, Florida, USA
- [54] Töpfer K (2002): Editorial for Int J LCA on the Launch of the UNEP-SETAC Life Cycle Initiative. Int J LCA 7 (4) 191
- [55] United Nations Conference of Environment and Development (UNCED), Rio de Janeiro, June 1992
- [56] World Summit on Sustainable Development, Johannesburg, September 2002
- [57] Klöpffer W (2003): Life-Cycle Based Methods for Sustainable Product Development. Int J LCA 8 (3) 157–159
- [58] Fava JA (2002): Life Cycle Initiative: A Joint UNEP/SETAC Partnership to Advance the Life-Cycle Economy. Int J LCA 7 (4) 196–198
- [59] Udo de Haes HA, Jolliet O, Norris G, Saur K (2002): Life Cycle Initiative: Background, Aims and Scope. Int J LCA 7 (4) 192–195
- [60] UNEP's Life Cycle Initiative Structure (2005): <<http://www.uneptie.org/pc/sustain/lcinitiative/participation.htm>>
- [61] Sonnemann G (2003): International Life Cycle Panel: Decisions for 2003. Int J LCA 8 (2) 61
- [62] UNEP/SETAC home page <<http://www.uneptie.org/pc/sustain/lcinitiative/home.htm>>
- [63] Rebitzer G, Hunkeler D (2003): Life Cycle Costing in LCM: Ambitions, Opportunities, and Limitations. Discussing a Framework. Int J LCA 8 (5) 253–256
- [64] Suh S (2003): Input-Output and Hybrid Life Cycle Assessment. Int J LCA 8 (5) 257
- [65] Brundtland GH (1987): Our Common Future. Oxford University Press. Oxford 1987
- [66] Klöpffer W, Renner I (2003): Life Cycle Impact Categories – The Problem of New Categories & Biological Impacts – Part I: Systematic Approach. SETAC Europe, 13th Annual Meeting Hamburg, Germany, 27 April–1 May 2003
- [67] Renner I, Klöpffer W (2005): Untersuchung der Anpassung von Ökobilanzen an spezifische Erfordernisse biotechnischer Prozesse und Produkte. Forschungsbericht 201 66 306 UBA-FB 000713. UBA Texte 02/05 Berlin 2005 <<http://www.umweltbundesamt.de>>
- [68] Ahlf W (2005): Fourth SETAC World Congress and 25th Anniversary – A First Stockage from a European Perspective. SETAC Globe 6 (2) 7–8
- [69] Huppes G. (1994): A General Method for Allocation in LCA. In: Huppes G, Schneider F (eds) (1994), Proceedings of the European Workshop on Allocation in LCA at the Centre of Environmental Science (CML) of Leiden University, Leiden 24th and 25th of February 1994. Under the Auspices of SETAC-Europe, Brussels, pp 74–90
- [70] Huppes G. (1993): Chapter 4.2 Standard methodology for LCA. In: Huppes G (1993): Macro-environmental policy. Principles and design. Elsevier, Amsterdam
- [71] Hunkeler D, Rebitzer G (2005): The Future of Life Cycle Assessment. Int J LCA 10 (5) 305–308
- [72] Hertwich G (2005) (ed): Special Issue on Consumption and Industrial Ecology. J Industrial Ecology 9 (1–2) 1–298
- [73] Hertwich G (2005): Life Cycle Approaches to Sustainable Consumption. A Critical Review. Environ Sci Technol 39 (13) 4673–4684
- [74] Grahl B, Schmincke E (2005): The Role of LCA in ISO Type III Environmental Declarations. Submitted to Int J LCA
- [75] Scholz N (2005): SETAC Sustainability Advisory Group. Call for a Round Table Debate. SETAC Globe 6 (4) 9–11

Received: December 2nd, 2005

Accepted: December 5th, 2005

OnlineFirst: December 6th, 2005